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Subjects for the study were three pairs of experienced curlers. Three curling stones were used for the experiment, as nearly alike in physical characteristics and weight as possible. Each stone received a total of ninety trials. For the forty-five odd-numbered trials the stones were swept, and for the forty-five even-numbered trials they were permitted to run unaffected. After each trial, linear distance and lateral deviation for each stone were measured and recorded.

A ten foot aluminum roller conveyor gave constant impetus to the stones. One end of the conveyor was supported 27 inches above the ice surface and the other end rested on the ice. A ramp, constructed of slush and allowed to freeze, permitted smooth transition of the stone from the conveyor to the ice. Torque was applied as the moving stone brushed against the leather-bound bristles of a curling broom fixed at the foot of the ice ramp.

Data were treated statistically to determine whether sweeping modified the linear distance of a moving stone, to determine whether sweeping modified the lateral deviation of a moving stone, and to determine whether there were differences between individual curling stones.

Conclusions were drawn that sweeping caused a moving stone to achieve a greater linear distance than it would normally and that sweeping reduced the degree of lateral deviation caused by the curling action of a moving stone. Sweeping also altered the condition of the ice surface. The degree of modification of linear distance and lateral

deviation was greater in the later trials. The degree of lateral deviation was consistent for the three stones, but the linear distances achieved varied considerably.

A STUDY OF THE EFFECT OF SWEEPING ON THE DISTANCE AND DIRECTION OF A MOVING CURLING STONE

by

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APPROVAL SHEET

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Although there is little evidence establishing the origin of the sport of curling, the strongest claim to the game seems to rest with the Scots. Study of the etymology of the game, of uncommon words that are common to curling - bonspiel, hack, crampit - leads experts to the conclusion that curling began in Scotland sometime prior to 1500. The oldest curling stone in existence was found in Scotland, near Stirling, and is dated 1511.

Played on ice, the modern game of curling has been standardized to an area or rink 138 feet long and 14 feet wide on which, at either end, have been inscribed three concentric circles. These circles, referred to as the house, measure 12 feet, 8 feet, and 4 feet in diameter. Each of the four members of two opposing teams will, alternately and in rotation, deliver two stones from one end of the rink to the house at the opposite end. Instructions for delivery of the stone such as desired objective, weight or speed, and the direction of curl are determined and directed by the skip. Other members of the team, in order of their positions, are lead, second, and vice-skip. Curl of the 42 pound polished granite stone is determined at release by twisting the handle clockwise for a curl to the right, or counterclockwise if a left curl is desired. When all sixteen stones have been delivered, one end has been completed; standard matches consist of eight or ten ends.

Once a stone has been delivered and is proceeding toward the opposite end of the rink, its progress can in no way be impeded. However, if the stone shows signs of falling short of the desired target, the skip will command, "Sweep!," and the two curlers, other than himself and the person who delivered the stone, will use their brooms to energetically sweep the ice in front of the stone, being careful not to touch it. The sweeping, therefore, is performed in an attempt to cause the stone to travel a greater distance than it would have had it not been swept. Sweeping is also used to cause a stone to "hold its line," that is, to prevent the stone from curling as much as it would ordinarily.

Statement of the Problem

This study attempted to determine the effect of sweeping on the distance and direction of a moving curling stone. The study undertook the examination of the following questions:

1. Does sweeping cause a moving curling stone to achieve a greater linear distance than will an unswept stone traveling at the same velocity?
2. Does sweeping reduce the degree of lateral deviation caused by the curling action of a moving stone?
3. Are there differences between individual curling stones?

Definition of Terms

Draw - lateral swing of stone during its movement up the ice. Amount of arc or curl.

<u>End</u> - inning, or division of a game, played from one end of the sheet to the other.

<u>Hack</u> - an immovable brace for the foot in or on ice at point of delivery.

<u>Heavy ice</u> - dull ice.

<u>Hog line</u> - lines drawn on ice in front of goal, which stone must clear to be in play. (32 feet in front of each hack with 72 feet between them.)

<u>House</u> - goal, designated by circles.

<u>In turn</u> - stone turning clockwise as it travels; curls to the right.

<u>Keen ice</u> - fast ice.

<u>Off the broom</u> - stone not played toward skip's broom.

<u>Out turn</u> - stone turning in counter-clockwise direction; curls to the left.

<u>Pebble</u> - roughening of ice surface by "mist spray" after flooding. This allows air to enter cup on bottom of stone.

<u>Rink</u> - sheet of ice. Also, group of players making up team.

<u>Rock</u> - another term for stone.

<u>Skip</u> - captain of team of players.

<u>Weight</u> - speed at which stone is delivered.

CHAPTER II

REVIEW OF LITERATURE

Sweeping has been an integral part of curling for over 400 years and while many claims have been made as to its importance, to date little information or scientific examination of its effect or even its necessity has been established.

Two considerations of the importance of sweeping have been that sweeping is helpful in generating enthusiasm and team morale among participants of the game, and that it is a means of keeping warm in sub-freezing temperatures. Both of these ideas have merit but they are generally considered to be of secondary importance as both may be accomplished in some other manner.

An examination of the literature on curling specifically advances the following theories with regard to sweeping:

1. Sweeping is a carry-over from earlier times when it was necessary on natural ice to remove foreign materials from the path of the stone.
2. Sweeping creates friction causing momentary melting of ice to allow the stone to slide farther.
3. Sweeping creates a vacuum, or low pressure area, into which the stone is drawn.
4. Sweeping reduces the amount of curl a stone will take, thus holding it to a straight line.

Many authorities accept one or more of these theories for the importance of the sweeping technique. The examination in this study considered three general aspects of sweeping:

1. Sweeping to keep ice free of foreign materials.
2. Sweeping to lengthen the distance a stone will travel.
3. Sweeping to reduce the amount of curl of a stone.

Sweeping to Keep Ice Free of Foreign Materials

The most detailed account of curling ever written is John Kerr's History of Curling. Although published in 1890, it is still recognized as a foremost authority on the sport. Kerr noted, "It is the broom that wins the battle. Every good curler knows that." (6:407) While he gave no evidence to support that claim, the importance of sweeping outdoor ice was made clear. Rules of curling at the turn of the century permitted sweeping the stone only after it reached the "middle line" - a line parallel to and midway between the two tee lines. However, the final sentence of Rule 12, General Rules of the Game, stated: "When snow is falling, a player's party may sweep stones of their own side from tee to tee." (6:393) McWhirter and Thiessen (7) urged "gently brushing" every shot to maintain a clean surface for the rock.

Ernie Richardson, one of curling's foremost contemporary experts, claimed that the ice surface itself would determine the effectiveness of the sweeping.

> On very keen ice (such as the newer artificial plants produce) sweeping can mean the difference in winning or losing a game. If the ice surface is frosty,

> sweeping will help polish a path and thus extend a stone's distance. On the other hand, about the only positive effect that sweeping will produce on heavy, sticky ice is to help keep the curlers warm and in the game. (9:69)

Today, much curling is still being done on natural ice where it is often necessary to brush snow, frost, twigs and other materials out of the path of the running stone. Indoor ice is generally free from most materials, but it is still possible to clear broomstraws or droppings of pipe tobacco from the stone's path.

Sweeping to Lengthen the Distance a Stone Will Travel

In examining the effect of sweeping upon the length of run of a stone, no attempt was made to examine the physical laws which may have caused the extended run.

Jessup (5) noted in 1923 that energetic sweeping in front of a slowing stone would draw it on "like a needle attracted to a magnet." While there is no magnetic attraction, White, two years later made the following observation:

> This sweeping not only clears the ice of all small particles which would naturally obstruct the progress of the stone, but also creates a vacuum through which the stone glides much more easily than when confronted by the resistance of air. It is surprising how this sweeping effects [sic] the progress of the stone. It actually seems to take on momentum as though the broom had the same power over it that a magnet has over metal. (12:113)

Richardson (9) subscribed to the belief that the melting effect caused by the pressure of the broom on the ice causes lubrication which permits the stone to slide farther. Also, he cited Bernoulli's theorem which stated simply, "air in motion exerts less pressure on an object than air at rest." Thus, it is the low pressure area and not a true vacuum which permits the stone to move farther. "Ergo," he said, "a stone that is strongly and properly swept will travel farther than one that is not." (9:99) Welsh, in Beginners Guide to Curling, concurred with Richardson's explanation of the importance of sweeping.

H. E. Weyman (11) reiterated the claim of a vacuum being created in front of the stone as a result of sweeping. It should be noted here that the term "vacuum" may refer to a low pressure area and not a true vacuum. The terms were, however, used interchangably throughout the literature.

Sweeping to Reduce the Amount of Curl of a Stone

It is, on occasions, desirable to attempt to reduce the amount of curl on a stone or to attempt to keep the stone traveling in a relatively straight line. This occurs when the weight of a stone is not a factor but the stone may have been delivered narrow of the broom; that is, between the broom and the target. For the stone to draw normally would be to miss the target. Thus, the command would be, "Sweep!"

McWhirter and Thiessen (7) saw sweeping as being essential to curling in that it allows the stone to go farther and to develop less curl. Richardson stated:

> Generally speaking, all stones should be swept as soon as they leave the curler's hand. Too, sweeping as soon as the rock has started its run is more beneficial than when the stone is slowing down at the end of its run and its momentum is being rapidly lost.
>
> . . . the stone begins to bend only when its momentum slows down and the rotational force overcomes its forward force. Thus, if a stone is delivered inside the skip's

> broom, immediate sweeping will help to prolong the straight line of delivery and delay the moment when the rock begins to curl. (9:71)

In addition, sweeping reduces the amount of draw of a stone keeping the stone on a straighter course so that the sweepers can bring a stone past a guard and make all the difference between a hit and a miss. (10:93)

While the value of vigorous sweeping is evident to nearly all curlers, most of their claims are based on their own observations. There are, however, three tests that have been conducted in an attempt to validate the claims supporting the technique of sweeping. All three tests were compiled and presented in Weyman's An Analysis of the Art of Curling. (11:39-42)

Tests 1 and 2 were conducted on natural ice at St. Moritz, Switzerland, on January 13 and 15, respectively, in 1924. Tests used a sloping trestle composed of boards covered over with snow and then iced. One end of the trestle was 3 feet above the ice and the other end was finished off even with the ice. The same stone was used throughout and an in-turn was applied to it.

Results of Test 1 - variation of averages of 6 to 12 metres in favor of the swept stones over the unswept stones.

Results of Test 2 - variation again of 5 to 12 metres on runs of 25 to 34 metres in favor of the swept stones.

Weyman noted that variations were due to factors difficult to keep constant: smoothness or roughness with which the stone took to ice, the stone passing over the same track, variations from smooth to rough ice, amount of torque applied to the stone, and transitory variations in the state of the ice.

A third test was conducted on indoor artificial ice in Toronto, Ontario, in 1961. A machine, duplicating a curler's delivery swing, delivered three stones. One stone was swept, the other two were unswept. The test revealed that the second unswept stone traveled 4 feet 6 inches farther than the first, but the swept stone traveled 18 feet 7 inches farther than the first stone. It was also noted that the swept stone remained closer to the center line than either of the other two, indicating that sweeping holds a stone on a straighter line.

Although the validity of the three tests may be questionable due to the uncontrolled variables and the meager number of trials performed, they are the only tests to date to be found in curling literature to attempt to evaluate the effects of sweeping. Because of that fact, numerous books base their sweeping claims on those Swiss and Canadian tests.

CHAPTER III

PROCEDURE

In an attempt to determine the effect of sweeping on the distance and direction of a moving curling stone, experiments were carried out on December 26 and 28, 1970, in the curling rink of the Hershey Country Club, Hershey, Pennsylvania.

Subjects

Three pairs of experienced curlers were selected from the club membership to perform the sweeping duties required for the experiment. The term "experienced curlers" is defined as curlers with more than five years active curling experience and the sweeping ability of each subject will be considered equally effective to that of every other.

Materials for Experiment

Three polished granite curling stones were selected for use in the experiment. All three stones had the same physical characteristics such as running surface and weight. The stones were marked I, II, and III so that it would be possible to distinguish any one of them from the others throughout the testing.

It was necessary to devise a means of giving constant impetus to each stone and for this purpose an aluminum roller conveyor was selected. The conveyor was 10 feet long, 12 inches wide and consisted of seventy-eight $1\frac{1}{2}$ inch ball-bearing rollers set one-fourth of an inch apart. Due to the size of the rollers and their close proximity to each other, it was possible for the stone to roll smoothly from one end of the conveyor to the other. There was no lateral movement of the stone possible on the conveyor. It was necessary to apply torque as the stone reached the ice surface. An ordinary curling broom, its bristles bound by a pair of leather gloves and held in place by three curling stones, was used to brush against the stone to apply the torque simulating a normal curling delivery.

Preparation of Ice Sheet

The ice sheet used for the experiment was prepared in precisely the same manner as it would be for a curling match. A large mop was run over the entire ice surface to pick up any dirt which had accumulated. The ice was then pebbled to prepare the surface for the running stones. The roller conveyor was placed so that one end rested on the ice at the back line and the other end was supported 27 inches above the surface of the ice. Because there was a three inch drop from the edge of the conveyor to the ice surface, it was necessary to construct a ramp out of slush and snow to permit the stone smooth access to the sheet. The ramp was constructed, smoothed off, and allowed to freeze prior to testing. The three curling stones were then placed at the foot and to the right of the ice ramp and held the leather-covered broom. Various positions were tested until one was found which permitted the desired amount of torque to be applied, giving the in-turn to the stone without affecting its direction or path. Droplets of water froze the three stones to the ice so they became immovable. (Figure 1)

Prior to testing, as well as throughout the tests, checks were made of various conditions. Throughout the experiments, the atmospheric temperature varied from 34° to 35°F. at the level of the ice. Brine temperature (that refrigerant which causes artificial ice to freeze) and ice temperature remained constant throughout at 20° and 25° F., respectively.

Technique for Gathering Data

It was decided that each of the three pairs of subjects would sweep each of the three stones being used. In a normal eight-end match, any pair of curlers would sweep a total of forty-eight stones if they swept every one. To avoid introducing a fatigue factor, therefore, each stone received a total of ninety trials - forty-five swept and forty-five unswept. For each series of trials, swept stones were alternated with the unswept stones; trial one was swept, trial two was unswept, trial three was swept and so on throughout the ninety trials for each stone. Testing was carried out in this manner for Stone I, Stone II, and Stone III. Also, ice preparations were repeated prior to testing each of the three stones so conditions were as nearly alike as possible.

Stones were placed at the top of the conveyor and were released so that their only momentum was that of their own mass on the incline. Each stone was introduced onto the ice at the same place each time. Stones being swept were swept as soon as they touched the ice sheet and until they came to rest at the opposite end of the rink. (Figure 2)

FIGURE 1

APPARATUS FOR GIVING IMPETUS AND APPLYING TORQUE TO STONES

FIGURE 2

SUBJECTS SWEEPING

The alternate stones were not swept at all, nor was their progress in any way affected by a human factor.

Measurement of the stones was accomplished using two methods. The linear distance was measured using a steel tape that was stretched along the side of the ice sheet and measured the distance the stone traveled from the edge of the ice ramp to the center of the stone when it came to rest. Lateral deviation, which was to the right of the point of release due to the in-turn given the stone, was measured from the outer edge of the stone to the edge of the ice sheet. A three-metre stick was used for this measurement and the point where the metre stick and the steel tape met provided both measurements for the stone. (Figure 3) Distance indicated by the metre stick was then subtracted from 79 inches (measurement from edge of ice to outer edge of stone at the point of release) to find the degree of lateral deviation of the stone. All stones were measured in like manner.

The procedures used in this experiment are based on Swiss tests mentioned earlier and are documented by Weyman. (11:39-40) There was, however, an attempt to control variables such as having stones released from the same point each time, constant ice conditions, and a smooth transition from incline to ice. Another important variable was the amount of torque applied to the stone. Throughout the experiment the number of complete turns made by the stone remained relatively constant at three to four turns, depending upon the length of run of the stone. This is consistent with suggested curl for best performance of a stone. (10:83, 11:41)

FIGURE 3

MEASUREMENT TECHNIQUE

The requirements for length of run of stones throughout the testing were determined by the range of distances a stone is permitted in regulation play. According to official rules for the game of curling, release of the stone must occur prior to its reaching the near hog line, and the length of run must allow the stone to travel beyond the far hog line for it to remain in play. Any stone coming to rest between the hog lines or traveling beyond the far back line is removed from play immediately. On this basis, the minimum distance a stone may travel is 72 feet - the distance between the two hog lines. The maximum distance a stone may travel and still remain in play is 132 feet - the distance from the near hack to the far back line. In addition, it was necessary to determine whether the impetus given each stone by the conveyor was consistent throughout the testing. For this reason, ten preliminary trials were made in which the stones were released onto the ice and were permitted to run unaffected either by sweeping or by the application of torque. The variation of up to six feet was felt to be due to stones passing over the same track on the ice and not to inconsistency in the performance of the roller conveyor.

Treatment of Data

The data recorded were treated statistically to determine:

1. if sweeping modified the linear distance achieved by a stone;
2. if sweeping modified the degree of lateral deviation of a stone;
3. if there was a difference between individual curling stones.

An analysis of variance technique using a 2 x 3 factorial design was employed. In treating the data for each stone, trials were paired (first swept trial with first unswept trial, second swept trial with second unswept trial) and differences between each pair were determined. Fisher's "t" test for the significance of difference between correlated means was the statistical method used for treating the data.

Summary

Three pairs of subjects were used to sweep each of three curling stones throughout the experiment. Each stone received ninety trials, for forty-five of which it was swept and for forty-five of which it ran unaffected. An aluminum roller conveyor was used to give constant impetus to the stones within the range of distances normally achieved in a curling match. Both linear distance and lateral deviation for each trial were measured and recorded. Data were treated statistically to determine the effect of the sweeping technique.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

The purpose of this study was to determine the effect of sweeping on the distance and direction of a moving curling stone. The study undertook to examine whether the sweeping technique caused any increase in the linear distance achieved by the stones, or if it in any way affected the degree of lateral deviation caused by the curling action of the stones.

The subjects selected for this study were three pairs of experienced curlers. Three curling stones as nearly alike as possible in appearance and weight were used for the experiment. Each stone was subjected to a total of ninety trials. In forty-five of the trials the stones were swept, and for the other forty-five they were permitted to run unaffected. The conditions of being swept or unswept were alternated for the odd and even runs of the stones, respectively.

After each trial, the linear distance and the lateral deviation for each stone were measured and recorded. Raw scores for the three stones on each trial are presented in Appendixes A, B, and C.

A series of null hypotheses was formulated and a difference significant at the 5 per cent level of confidence was considered an acceptable standard at which to find an hypothesis untenable. The hypotheses considered were:

1. Sweeping causes no significant modification in the linear distance achieved by a moving curling stone;

2. Sweeping causes no significant modification of the degree of lateral deviation caused by the turning action of a moving curling stone;
3. There is no significant difference between individual curling stones.

Modification of Linear Distance

The first null hypothesis stated that:

Sweeping causes no significant modification in the linear distance achieved by a moving curling stone.

An analysis of variance technique was used to determine if there were significant statistical differences between the linear distances achieved in the swept and unswept trials of the three stones.

A significant difference was found between the mean scores of the swept and unswept stones. The null hypothesis was rejected at the 5 per cent level of confidence. These results appear in Table I, page 21.

Modification of Lateral Deviation

The second null hypothesis stated that:

Sweeping causes no significant modification of the degree of lateral deviation caused by the turning action of a moving curling stone.

An analysis of variance technique was used to determine if there were significant statistical differences in the degree of lateral deviation of the stones with regard to swept and unswept conditions.

TABLE I

ANALYSIS OF VARIANCE BETWEEN STONES IN LINEAR DISTANCE UNDER SWEPT AND UNSWEPT CONDITIONS

Source of Variance	Sum of Squares	df	Mean Square	F
Between treatments	1096.91	1	1096.91	9.727*
Between stones	2224.91	2	1112.45	9.865*
Interaction	61.19	2	30.95	.274
Within stones	29771.16	264	112.76	
Total	33154.17	269		

* Significant at the .05 level of confidence.

A significant difference was found in lateral deviation between the mean scores of the swept and unswept stones. The second null hypothesis was found untenable at the 5 per cent level of confidence. These results appear in Table II, page 23.

Fisher's "t" test of significance between correlated mean differences was used to determine whether there was a significant statistical difference between the swept and unswept treatments between paired trials of the three individual stones. The results revealed that there was a significant difference at the 5 per cent level of statistical confidence between the treatments in both linear distance and lateral deviation for each of the stones. These results appear in Table III, page 24.

The writer was interested in knowing further if the results of the two treatments might vary with the stage of the contest in which sweeping was employed. An examination of the raw data indicated that perhaps a significant statistical difference might exist between the linear distance and lateral deviation as affected by the swept and unswept conditions within the first and second halves of the trials. Therefore, the data were subjected to Fisher's "t" tests of significance between correlated mean differences to determine if such differences did exist within each of the two halves of the trials.

An examination of the "t" ratios for both linear distance and lateral deviation within each half of the trials indicated a significant difference between the sweeping conditions in all but two cases. Only the first half "t" ratios for the lateral deviation of Stone I and for the linear distance of Stone III failed to show any statistical

TABLE II

ANALYSIS OF VARIANCE BETWEEN STONES IN LATERAL DEVIATION UNDER SWEPT AND UNSWEPT CONDITIONS

Source of Variance	Sum of Squares	df	Mean Square	F
Between treatments	10565.63	1	10565.63	56.06*
Between stones	193.22	2	96.61	.512
Interaction	1456.72	2	728.36	3.864
Within stones	49756.94	264	188.47	
Total	61972.51	269		

* Significant at the .05 level of confidence.

TABLE III

SIGNIFICANCE OF MEAN DIFFERENCES UNDER SWEPT AND UNSWEPT CONDITIONS

Stone	N	M_D	t
Stone I			
Linear distance	45	4.73	7.166*
Lateral deviation	45	5.98	2.027*
Stone II			
Linear distance	45	4.66	5.974*
Lateral deviation	45	16.45	5.358*
Stone III			
Linear distance	45	2.69	4.483*
Lateral deviation	45	15.08	6.080*

* Significant at the .05 level of confidence.

significance between the swept and unswept treatments. It was also noted that the mean differences were consistently greater in the second twenty-two trials than in the first twenty-three. These results appear in Table IV, page 26 and Table V, page 27.

Difference Between Curling Stones

The third null hypothesis stated that:

There is no significant difference between individual curling stones.

The assumption was made at the outset of the testing that individual curling stones were alike and would react to various treatments in the same way and to the same degree. The reaction of the stones to the treatments was noted with regard to linear distance and lateral deviation.

An analysis of variance between stones in linear distance under swept and unswept conditions showed a significant statistical difference between the stones. (See Table I, page 21.) The Scheffé test was used to determine where significant differences existed.

The results indicated a significant difference between Stones I and II and between Stones II and III, but no difference between Stones I and III.

An analysis of variance between stones in lateral deviation under swept and unswept conditions revealed no significant difference between the stones. These results appear in Table II, page 23.

Because of the significance of difference found between stones in linear distance, the third null hypothesis was found untenable at the 5 per cent level of confidence.

TABLE IV

SIGNIFICANCE OF MEAN DIFFERENCES IN LINEAR DISTANCE AND LATERAL DEVIATION UNDER SWEPT AND UNSWEPT CONDITIONS FOR FIRST HALF TRIALS

Stone	N	M_D	t
Stone I			
Linear distance	23	2.60	2.608*
Lateral deviation	23	2.30	.575
Stone II			
Linear distance	23	3.48	3.346*
Lateral deviation	23	16.71	3.308*
Stone III			
Linear distance	23	2.04	2.040
Lateral deviation	23	12.73	4.106*

* Significant at the .05 level of confidence.

TABLE V

SIGNIFICANCE OF MEAN DIFFERENCES IN LINEAR DISTANCE AND LATERAL DEVIATION UNDER SWEPT AND UNSWEPT CONDITIONS FOR SECOND HALF TRIALS

Stone	N	M_D	t
Stone I			
Linear distance	22	6.94	11.762*
Lateral deviation	22	14.65	4.103*
Stone II			
Linear distance	22	5.89	5.121*
Lateral deviation	22	16.18	4.317*
Stone III			
Linear distance	22	3.37	5.106*
Lateral deviation	22	17.54	4.474*

* Significant at the .05 level of confidence.

Interpretation of Data

The analysis of variance technique indicated a significant difference between the swept and unswept conditions for both the linear distance and the lateral deviation of the curling stones. Fisher's "t" test of significance between correlated means also indicated differences between the treatments in linear distance and lateral deviation for paired trials of each stone. Two purposes of sweeping the stone in curling, as previously stated, are to increase the linear distance that the stone will travel and to reduce the degree of lateral deviation caused by the curling action of the stone. An examination of mean scores and significance of difference between swept and unswept trials indicated that sweeping significantly extended the linear distance of a moving curling stone beyond its normal limit when it was allowed to run free. For each of the three stones, the mean scores of the swept trials were significantly greater than the mean scores of the unswept trials.

In examining the effectiveness of the sweeping technique with regard to the degree of lateral deviation, the results of Fisher's "t" test of significance between correlated means revealed that sweeping reduced the degree of lateral deviation caused by the curling action of the stone. For each stone, the lateral deviation was less for the swept stone than for the unswept stone, and the "t" ratios were significant in each case.

Although the use of Fisher's "t" test of significance of correlated means indicated that there was a significant difference between the treatments for the total number of trials, the mean differences were greater in the second half trials for each stone. In the two cases where the "t" ratios did not indicate significant differences between the treatments in the first half of the trials, the greater mean differences in the second half caused the total "t" ratios to show a statistical difference.

This observation indicated that the effect of sweeping may be more pronounced in the later stages of the curling match than at the beginning. If, as Richardson noted, the sweeping technique was more effective on keen ice, and if the early sweeping of the ice actually did cause the surface to become keener, then the sweeping technique would be more effective in the later stages of the contest. It may be concluded that the sweeping procedure has a cumulative effect on the condition of the ice between early and late stages of play so that sweeping in the third end may actually affect the stones played in the seventh end.

The analysis of variance technique used to evaluate the performance of the three stones under the swept and unswept conditions showed no differences between the individual stones in the degree of lateral deviation. In all cases, the stones reacted to the curl applied to them in similar manner and with no significant difference in degree. However, in the linear distance achieved by the three stones traveling at the same velocity, there was a significant statistical difference between the stones. As the physical properties and treatments of the three stones appeared to be alike, there seems to be no logical explanation for this difference. However, there is always the possibility that minute differences on the running surface could foster individual characteristics for each stone.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effect of sweeping on the distance and direction of a moving curling stone. The study undertook to examine whether the sweeping technique did cause an increase in the linear distance achieved by the stones, and if it in any way affected the degree of lateral deviation caused by the curling action of the stones.

Subjects for this study were three pairs of curlers, all of whom had more than five years curling experience. Three curling stones were used for the experiment, being as nearly alike in physical properties as possible. Each stone received a total of ninety trials, forty-five of which it was swept and forty-five of which it ran unaffected.

After each trial, the linear distance and the lateral deviation for each stone was measured and recorded.

Data were treated statistically to determine:

1. if sweeping modified the linear distance achieved by a stone;
2. if sweeping modified the degree of lateral deviation of a stone;
3. if there was a difference between individual curling stones.

An analysis of variance technique and Fisher's "t" test for the significance of difference between correlated means were the statistical methods used for treating the data.

The following results were obtained:

1. There was a difference between swept and unswept stones, significant at the 5 per cent level of confidence in favor of the swept stones, found in the linear distances of the total number of trials of the three stones.
2. There was a statistical difference significant at the 5 per cent level of confidence, found between swept and unswept stones in favor of the swept stones in the degree of lateral deviation for the total number of trials of the three stones.
3. A difference significant at the 5 per cent level of statistical confidence was found within each of the three stones in both linear distance and degree of lateral deviation; the difference in both cases was in favor of the swept stones.
4. The mean differences were greater in the second half of the trials for each stone than in the first half for both linear distance and degree of lateral deviation.
5. There was no significant statistical difference between the three stones tested with respect to the degree of lateral deviation.
6. A statistical difference significant at the 5 per cent level of confidence was found between the three stones in linear distance.

The findings of this study resulted in the following conclusions:

1. Sweeping causes moving curling stones to achieve a greater linear distance than they would if permitted to run unswept.
2. Sweeping reduces the degree of lateral deviation caused by the curling action of moving curling stones.
3. Sweeping alters the condition of the ice surface.
4. Sweeping modifies the linear distance and the degree of lateral deviation of each stone to a greater extent after several trials have been completed.
5. Under swept and unswept conditions, the degree of lateral deviation caused by the curl of the moving stone is consistent among individual stones, but, for no apparent reason, their linear distances vary considerably.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Anderson, Melvin G. "The History, Development and Techniques of Curling as an Interscholastic Sport." Unpublished Master's thesis, The State University of Iowa, Iowa City, 1941.

2. Curtis, Dar. Curling . . . Fun for Everyone. Winnetka, Illinois, 1959. (Copyright.)

3. Dier, J. C. (ed.). A Book of Winter Sports. New York: The Macmillan Company, 1922.

4. Hensel, Paul E. "The Parlance to Curling." Unpublished manuscript, Hershey, Pennsylvania, 1969.

5. Jessup, Elon. Snow and Ice Sports: A Winter Manual. New York: E. P. Dutton and Company, 1923.

6. Kerr, John. History of Curling. Edinburgh: David Douglas, 1890.

7. McWhirter, L. M., and R. D. Theissen. Instructor's Manual for Curling. Produced for the Provincial Youth Agency, Government of the Province of Saskatchewan, Regina, Saskatchewan, Canada.

8. Meddaugh, Ray C. How to Start a Curling Club. South Milwaukee, Wisconsin, 1965. (Copyright.)

9. Richardson, Ernie, Joyce McKee and Doug Maxwell. Curling. New York: David McKay Company, 1963.

10. Welsh, Robin. Beginner's Guide to Curling. London: Pelham Books, 1969.

11. Weyman, H. E. An Analysis of the Art of Curling. Levis, Province of Quebec, Canada, 1965. (Copyright.)

12. White, W. Dustin. The Book of Winter Sports. Boston: Houghton Mifflin Company, 1925.

APPENDIXES

APPENDIX A

Stone I

LINEAR DISTANCE AND LATERAL DEVIATION FOR
STONE I UNDER SWEPT AND UNSWEPT CONDITIONS

	Swept		Unswept	
Trials	Linear (feet)	Lateral (inches)	Linear (feet)	Lateral (inches)
1	95.25	48	92.58	3
2	90.08	26	94.75	13.5
3	92.67	18	93.33	20
4	103.33	44	103.42	31.5
5	107.58	51	103.33	34
6	101.25	7	103.83	35
7	107.75	55.5	94.25	28
8	106.83	54	102.33	51
9	97.50	10	82.75	40
10	94.50	23	93.25	46.5
11	93.25	36.5	92.17	51
12	95.08	40.5	91.92	36
13	95.67	50	92.08	41.5
14	97.75	59.5	92.67	29
15	98.42	48.5	93.25	40
16	85.83	42	90.67	51.5
17	93.0	26.5	97.42	37.5
18	99.92	44	96.67	46.5
19	103.08	21	99.58	45
20	99.92	57	100.58	49.5
21	103.50	54	98.17	53.5
22	107.92	48	105.0	49
23	106.92	53	103.0	31.5
24	110.33	9.5	100.75	36.5
25	111.33	47	107.17	28.5
26	110.75	43	100.67	40.5
27	110.50	48	105.08	54
28	111.0	52	103.17	46
29	111.58	41	103.58	50
30	112.75	32	105.0	41
31	110.75	42	103.33	32.5
32	111.08	37.5	104.67	40
33	109.92	7.5	103.08	52.5
34	111.75	21	101.83	48
35	110.17	18.5	103.08	61

STONE I (continued)

Trials	Swept Linear (feet)	Swept Lateral (inches)	Unswept Linear (feet)	Unswept Lateral (inches)
36	109.0	47	103.58	52
37	110.75	28	102.75	58
38	109.58	36	105.0	44
39	111.08	21.5	103.17	36.5
40	111.58	18	103.75	41
41	111.67	31	102.67	45
42	111.33	23.5	104.08	49.5
43	111.83	10	103.42	42.5
44	110.92	8.5	104.25	39
45	111.67	28	103.67	35

APPENDIX B

Stone II

LINEAR DISTANCE AND LATERAL DEVIATION FOR
STONE II UNDER SWEPT AND UNSWEPT CONDITIONS

	Swept		Unswept	
Trials	Linear (feet)	Lateral (inches)	Linear (feet)	Lateral (inches)
1	94.17	60	89.75	49
2	88.92	1	86.25	47
3	91.67	35.5	88.33	47.5
4	93.17	54	87.33	32
5	88.33	19	88.67	60
6	94.75	30	89.08	51.5
7	83.67	14	95.08	53
8	92.08	29	90.17	42
9	88.25	30	89.67	60.5
10	86.58	16	87.08	15
11	89.33	28	88.58	17
12	90.58	21.5	89.33	31
13	90.92	18	88.83	53.5
14	89.67	26.5	86.33	62.5
15	90.75	15	87.25	56
16	87.25	39.5	86.92	56
17	92.67	25	90.08	47.5
18	100.0	50	90.25	61
19	101.75	30.5	94.92	44.5
20	97.25	32	86.25	51.5
21	100.58	28.5	87.25	50
22	101.67	41	94.67	44.5
23	102.08	46	93.83	42
24	100.92	50	96.08	28.5
25	101.75	36.5	95.83	50
26	103.25	43	94.25	61.5
27	102.83	48	96.50	57.5
28	101.92	30.5	95.75	56
29	103.08	37	98.50	48
30	100.75	33.5	97.92	60.5
31	110.83	28.5	106.83	42
32	105.42	42	104.17	44.5
33	106.33	5.5	86.25	63
34	104.92	30	105.0	30
35	102.50	19	83.25	32

STONE II (continued)

Trials	Swept		Unswept	
	Linear (feet)	Lateral (inches)	Linear (feet)	Lateral (inches)
36	98.50	29.5	86.50	64
37	99.25	66	95.17	18.5
38	102.50	5	98.58	8.5
39	102.17	15	105.83	23
40	101.0	34	97.75	51
41	101.25	6	98.17	44
42	102.58	12	97.50	51.5
43	102.08	14.5	98.0	60.5
44	103.0	22	95.25	53
45	102.58	23.5	96.58	49.5

APPENCIX C

Stone III

LINEAR DISTANCE AND LATERAL DEVIATION FOR
STONE III UNDER SWEPT AND UNSWEPT CONDITIONS

	Swept		Unswept	
Trials	Linear (feet)	Lateral (inches)	Linear (feet)	Lateral (inches)
1	59.58	25.5	65.75	3
2	68.67	17.5	71.17	13.5
3	70.08	19	70.67	40
4	72.42	38	73.25	48
5	73.67	22	73.50	47
6	80.75	41	81.25	22.5
7	82.50	32	80.67	29.5
8	72.0	28	71.08	34.5
9	80.58	42.5	81.33	48
10	91.92	34	94.08	56
11	84.33	31	87.17	54
12	86.17	39.5	81.17	40.5
13	93.25	29	85.83	39
14	81.75	37	83.67	52
15	92.92	40	84.17	47
16	109.50	41	104.33	64
17	105.75	36.5	106.33	51
18	107.25	28.5	104.50	55.5
19	109.75	30	107.80	44.5
20	110.08	8.5	105.33	37
21	110.0	11	105.58	42
22	109.83	30	93.67	65
23	110.42	26	104.67	47
24	106.58	39.5	106.83	31
25	109.67	18	107.33	50
26	110.08	25.5	106.92	45.5
27	111.17	15	108.08	34
28	111.58	30.5	107.17	41
29	110.67	18	106.50	47.5
30	111.42	16	106.67	45
31	108.0	28	107.58	61
32	111.25	54	113.75	57
33	113.25	58	110.33	51
34	113.50	50.5	110.50	38
35	116.83	43.5	113.17	51

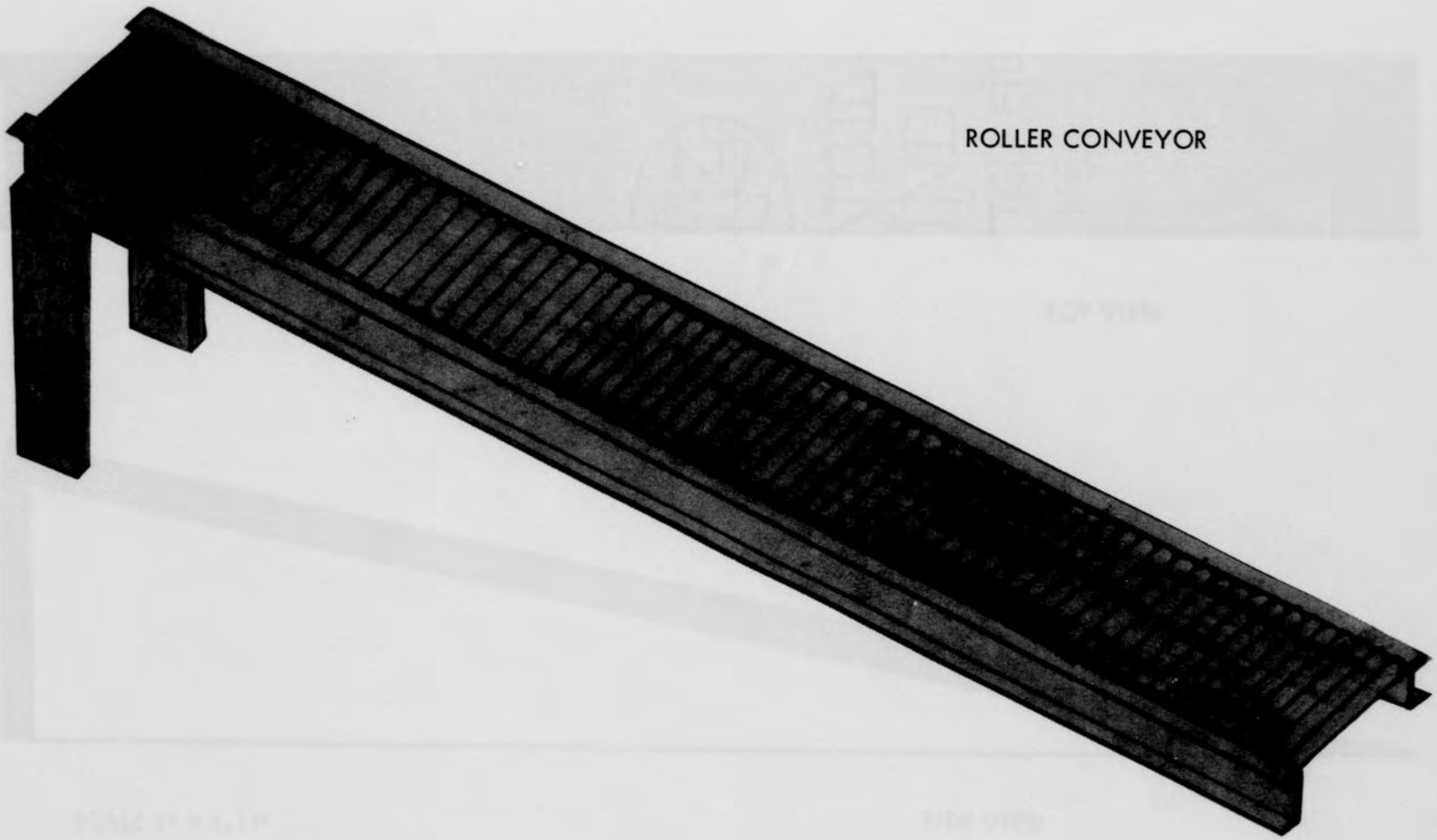
STONE III (continued)

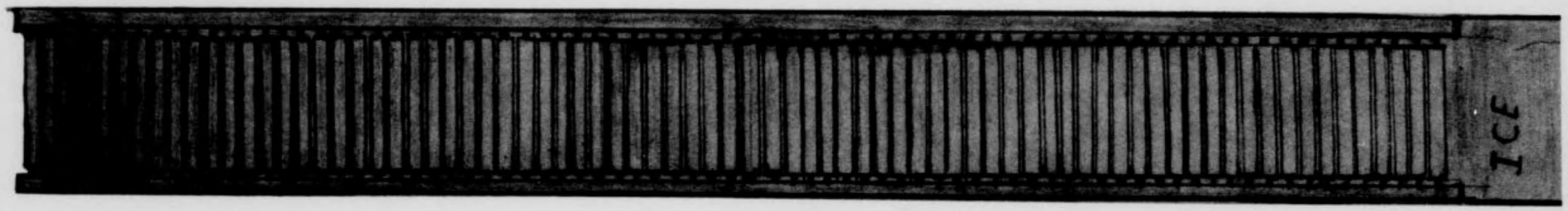
Trials	Swept Linear (feet)	Swept Lateral (inches)	Unswept Linear (feet)	Unswept Lateral (inches)
36	117.75	46.5	107.42	32
37	116.17	25	110.83	58
38	117.25	11	109.92	20
39	113.08	3	115.92	45
40	113.75	44.5	113.33	44
41	115.08	17.5	112.92	50.5
42	117.25	20	111.25	37
43	116.83	15	110.75	41
44	115.58	8.5	110.33	51
45	117.17	6.5	111.67	49.5

APPENDIX D

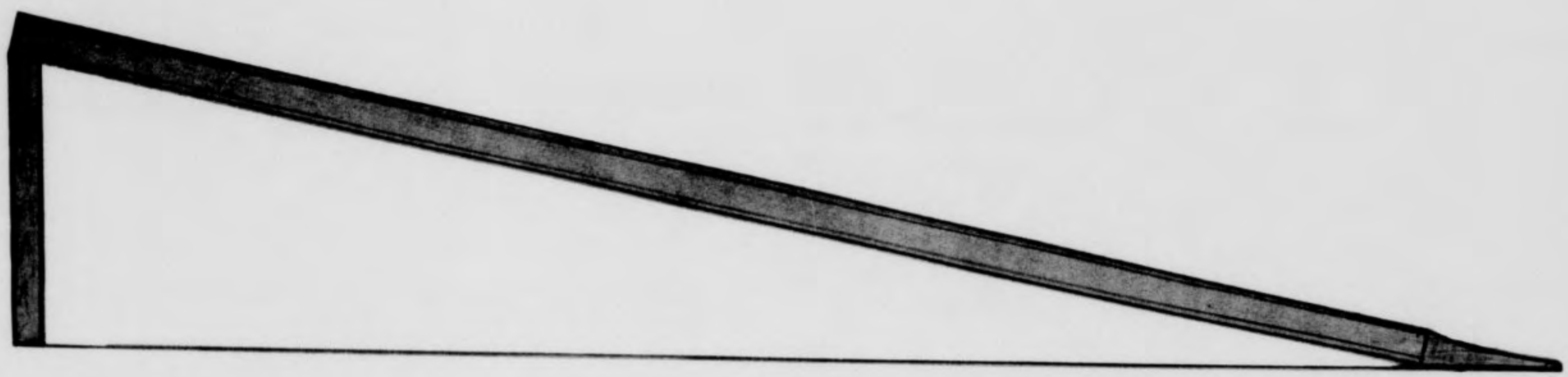
Roller Conveyor

ROLLER CONVEYOR





TOP VIEW

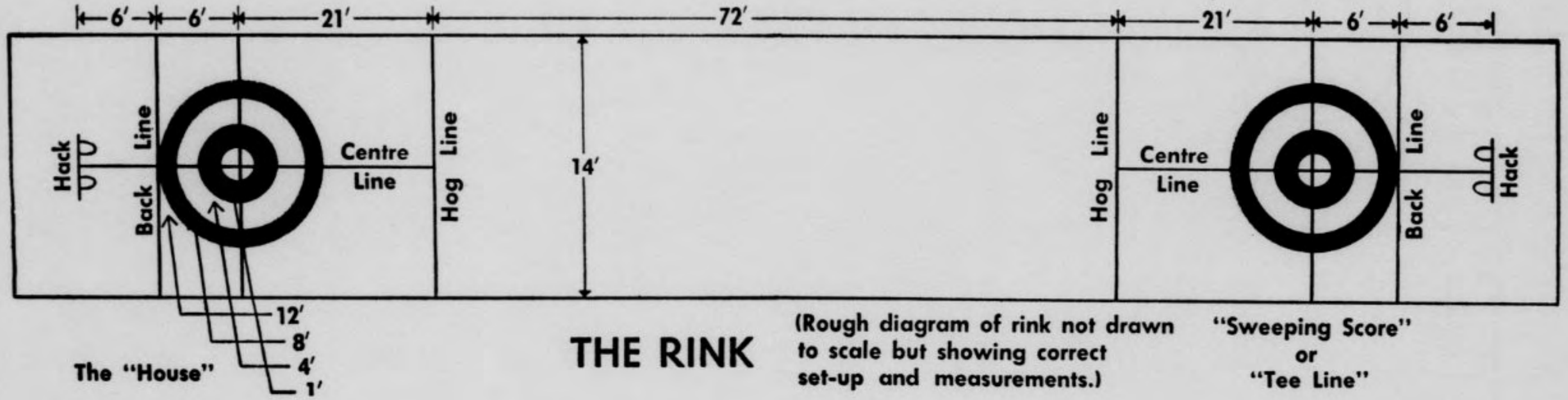


SCALE 1" = 1.11'

SIDE VIEW

APPENDIX E

The Rink



THE RINK

(Rough diagram of rink not drawn to scale but showing correct set-up and measurements.)